SUPPLEMENT ARTICLE

Hospitalizations and Deaths Due to *Salmonella* Infections, FoodNet, 1996–1999

Malinda Kennedy,[1] Rodrigo Villar,[3] Duc J. Vugia,[4] Therese Rabatsky-Ehr,[5] Monica M. Farley,[2] Margaret Pass,[6] Kirk Smith,[7] Perry Smith,[8] Paul R. Cieslak,[9] Beth Imhoff,[1] and Patricia M. Griffin,[1] for the Emerging Infections Program FoodNet Working Group[a]

[1]Centers for Disease Control and Prevention and [2]Georgia Emerging Infections Program, Atlanta; [3]Children's Clinics and the Department of Pediatrics, University of Arizona, Tucson; [4]California Department of Health Services, Berkeley; [5]Connecticut Emerging Infections Program, New Haven; [6]John Hopkins School of Hygiene and Public Health, Baltimore, Maryland; [7]Minnesota Department of Health, Minneapolis; [8]New York State Department of Health, Albany; and [9]Office for Disease Prevention & Epidemiology, Oregon Department of Human Services, Portland

Nontyphoidal *Salmonella* causes a higher proportion of food-related deaths annually than any other bacterial pathogen in the United States. We reviewed 4 years (1996–1999) of population-based active surveillance data on laboratory-confirmed *Salmonella* infections from the Emerging Infections Program's Foodborne Diseases Active Surveillance Network (FoodNet), to determine the rates of hospitalization and death associated with *Salmonella* infection. Overall, 22% of infected persons were hospitalized, with the highest rate (47%) among persons aged >60 years. Fifty-eight deaths occurred, for an estimated annual incidence of 0.08 deaths/100,000 population. These deaths accounted for 38% of all deaths reported through FoodNet from 1996 through 1999, and they occurred primarily among adults with serious underlying disease. Although *Salmonella* infection was seldom listed as a cause of death on hospital charts and death certificates, our chart review suggests that *Salmonella* infection contributed to these deaths.

Each year in the United States, nontyphoidal *Salmonella,* which is one of the most common bacterial pathogens, accounts for ~1.4 million foodborne infections and roughly one-quarter (26%) of the ~323,000 hospitalizations for foodborne infections [1, 2]. It is estimated that food-related *Salmonella* infections cost $0.5–$2.3 billion annually; deaths account for much of this cost [2]. However, few data are available to definitively attribute the high cost of these deaths to foodborne salmonellosis, because infected patients frequently have severe underlying diseases.

We reviewed population-based active surveillance data on laboratory-confirmed *Salmonella* infections ascertained during 1996–1999 in the Emerging Infections Program's Foodborne Diseases Active Surveillance Network (FoodNet) to determine the rates of hospitalization and death associated with *Salmonella* infection. In addition, to determine the proportion of persons who died as a direct result of their *Salmonella* infection, we conducted a follow-up survey of persons who died in 1996.

FoodNet was established in 1995 as a collaborative effort among the Centers for Disease Control and Prevention (CDC), selected state health departments and their academic partners, the US Department of Agriculture's Food Safety and Inspection Service (FSIS), and the US Food and Drug Administration. FoodNet conducts active surveillance for foodborne pathogens to better determine the burden of foodborne illness in the United States. FoodNet personnel ascertain culture-confirmed infections of 7 bacterial foodborne pathogens by communicating monthly with all clinical lab-

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[a] Working group members are listed at the end of the text.

Reprints or correspondence: Dr. Malinda Kennedy, Centers for Disease Control and Prevention, MS D63, 1600 Clifton Rd. NE, Atlanta, GA 30333 (mhkenned@hsph.harvard.edu).

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oratories in FoodNet surveillance areas (also known as "FoodNet sites").

In 1996, FoodNet conducted active surveillance in 5 FoodNet sites (Minnesota, Oregon, and selected counties in California, Connecticut, and Georgia). Between 1996 and 1999, the Foodnet surveillance population expanded to include the populations of the entire state of Georgia, the entire state of Connecticut, and selected counties in Maryland and New York, increasing from 14.3 million persons to 25.8 million persons.

METHODS

In identifying culture-confirmed cases of *Salmonella* infection from FoodNet data for 1996–1999, adults were defined as persons aged ⩾20 years. For patients with multiple isolates, we used the most invasive isolate in our analysis. We defined the case-fatality rate among cases for which outcome was recorded. We conducted the study in accordance with guidelines for human research as specified by the US Department of Health and Human Services.

Outpatients were monitored for 7 days after the date of culture-specimen collection, to determine whether they were hospitalized or died; hospitalized patients were monitored until they were discharged or died. Deaths were assessed by medical chart review or by interviews with physicians, hospital infection-control practitioners, or next of kin, depending on the site and the availability of information. Data were entered, transmitted to CDC using the Public Health Laboratory Information System, and analyzed with SAS software, version 6.12 (SAS) [3]. In addition, for those patients who died of *Salmonella* infection in 1996, hospital records were reviewed in depth by FoodNet staff using a standardized chart review form that collected detailed information, including symptoms, medical history, recent medications, and death-certificate information, when it was available. On the basis of the chart review, chart abstracters gave their opinion as to whether *Salmonella* infection contributed to deaths. *Salmonella* isolates from urine were first included in the surveillance data in 1999. Calculations involving particular serotypes were done with data for case patients whose isolates were serotyped; this included 93% of all patients, 95% of hospitalized patients, and 93% of patients who died.

RESULTS

From 1996 through 1999, *Salmonella* isolates were the second most frequently reported of the FoodNet pathogens, accounting for 11,225 (33%) of the 34,296 bacterial isolates (table 1). The proportions of infections due to other pathogens were as follows: *Campylobacter,* 44% of isolates; *Shigella,* 15% of isolates; *Escherichia coli* O157:H7, 5% of isolates; *Yersinia,* 2% of isolates; *Listeria,* 1% of isolates; and *Vibrio,* 0.5% of isolates. Excluding the 100 *Salmonella* isolates without a recorded specimen source, 91% were cultured from stool, 6.5% from blood, and 1.5% from urine. However, in 1999, when urine isolates were first included, 89% of *Salmonella* isolates were cultured from stool, 6% from blood, and 4% from urine. The 758 invasive *Salmonella* infections accounted for 57% of the 1335 invasive infections caused by the 7 bacterial pathogens. *Salmonella* infections accounted for 38% of the 153 deaths associated with these 7 pathogens (table 1). We were able to ascertain the hospitalization status for 9905 (88%) of patients with *Salmonella* infections. Of these, 22% were hospitalized: 76% at the time of specimen collection and 24% within 7 days after specimen collection. The median length of hospitalization was 3 days (range, 1–190 days). The highest rate of hospitalization was among persons aged ⩾60 years (47%), and the next highest rates were among persons aged 50–59 years (26%) and infants (25%) (table 2). Male and female patients were hospitalized with similar frequency. Persons hospitalized with *Salmonella* infection who subsequently died had a longer median length of hospital stay (6 days; range, 1–78 days) than hospitalized persons who survived (3 days; range, 1–190 days). The most common *Salmonella* serotypes isolated from hospitalized persons were Typhimurium (from 654 patients [31%]) and Enteritidis (from 269 patients [13%]), which is similar to the frequencies of isolation for all cases of *Salmonella* infection (Typhimurium, 27% of patients and Enteritidis, 14% of patients). However, for serotypes with ⩾10 isolates reported, the highest hospitalization rates were among patients infected with serotypes Choleraesuis (19 [76%] of 25 patients), Dublin (21 [70%] of 30 patients), Typhi (75 [65%] of 116 patients), and Paratyphi A (16 [55%] of 29 patients).

Table 1. Cases of infection and deaths associated with bacterial pathogens, FoodNet, 1996–1999.

Pathogen	No. (% of cases	No. (%) of deaths	Case-fatality rate, %[a]
Campylobacter	15,181 (44)	12 (8)	0.1
E. coli O157:H7	1734 (5)	16 (10)	0.9
Listeria	372 (1)	57 (37)	15.7
Salmonella	11,225 (33)	58 (38)	0.6
Shigella	4984 (15)	4 (3)	0.1
Vibrio	171 (<1)	3 (2)	2.6
Yersinia	629 (2)	3 (2)	0.6
Total	34,296 (100)	153 (100)	0.6

NOTE. For cases and deaths, % refers to the proportion of the total for all pathogens. For the case-fatality rate, % refers to the proportion of deaths among patients infected with the pathogen indicated.

[a] The case-fatality rate was calculated among persons with a known outcome. The percentages of patients with known outcomes were as follows: *Salmonella* infection, 82%; *Campylobacter* infection, 78%; *E. coli* O157 infection, 98%; *Yersinia* infection, 87%; *Vibrio* infection, 68%; *Listeria* infection, 98%; and *Shigella* infection, 80%.

Table 2. Hospitalization and death rates among persons with *Salmonella* infection, by age group, FoodNet, 1996–1999.

Age group, in years	No. of patients	Proportion (%) hospitalized[a]	Proportion who died (case-fatality rate)[a]
<1	1462	290/1159 (25)	1/1076 (0.1)
1–9	2823	354/2426 (15)	1/2190 (0.05)
10–19	1108	183/1017 (18)	0/947 (0)
20–29	1427	201/1319 (15)	2/1180 (0.2)
30–39	1404	238/1283 (19)	5/1167 (0.4)
40–49	1105	208/1016 (20)	10/927 (1.1)
50–59	708	164/637 (26)	5/575 (0.9)
⩾60	1188	494/1048 (47)	34/964 (3.5)
Total	11,225	2132/9905 (22)	58/9026 (0.6)

[a] Denominators are no. of persons with information available.

Whether or not the patient died within 7 days of culture collection was determined for 80% of all persons with *Salmonella* infection (9026 of 11,225), including for 88% of the 8275 patients who were outpatients at the time of culture collection and for 97% of the 1629 patients who were inpatients. There were 58 deaths, resulting in a case-fatality rate of 0.6% among the 9026 persons with known outcome. The case-fatality rate ranged from 0.9% in 1996 to 0.4% in 1998 but did not decrease significantly. This overall case-fatality rate did not differ significantly between men (0.6%) and women (0.7%). The case-fatality rate was highest (3.5%) among persons aged ⩾60 years and lowest among persons aged <20 years (table 2). Most of these fatal *Salmonella* infections (33 [57%] of 58) were invasive. Serotype specific case-fatality rates were not robust enough to make meaningful comparisons. However, the most common serotypes isolated from patients who died were Typhimurium (from 50% of patients), Heidelberg (7%), Enteritidis (7%), Dublin (3%), and Newport (3%). With the exception of serotype Dublin, these serotypes were also the most common serotypes isolated from all cases of *Salmonella* infection. However, the rate of isolation of serotype Typhimurium was proportionally higher for those who died.

Sixteen deaths among persons with *Salmonella* infections were reported through FoodNet active surveillance in 1996. Medical histories were available for 15 of the decedents. Their ages were 22–87 years: 6 were aged 40–49 years and 5 were aged ⩾70 years, and 8 were men (table 3). All of these patients were hospitalized. Of those with information available on symptoms before hospitalization, 53% had a fever, 43% had abdominal cramps, 40% had diarrhea, 21% had bloody stool, and 15% had vomiting. Two decedents had recurrent *Salmonella* infections. *Salmonella* was isolated from ⩾2 sources in 5 decedents: blood and stool in 3; blood and urine in 1; and blood, urine, and stool in 1. *Salmonella* was isolated from blood alone in 8 (53%) of the decedents, from stool alone in 1 (7%), and from peritoneal fluid in 2 (7%). *S.* Typhimurium was isolated from 6 of 14 decedents from whom the infecting serotype was known. Most deaths occurred among patients with major medical problems, including 3 infected with HIV, 3 with cancer or leukemia, and 2 with cirrhosis or alcoholism. Six of those who died were reported to have taken antimicrobial agents before symptom onset, and 13 received antimicrobial agents for treatment of their *Salmonella* infection. The median duration of illness caused by the *Salmonella* infection before death was 19 days (range, 1–122 days). The median duration of hospitalization was 6 days (range, 0–122 days). Eight decedents had medical complications recorded during their hospitalizations, including electrolyte imbalance, pneumonia, and cardiorespiratory failure. *Salmonella* infection was judged by the chart reviewers to have been responsible for or to have contributed directly to the deaths of 14 of 15 decedents with medical histories available (table 4). However, *Salmonella* infection was specifically listed as a cause of death on only 6 hospital charts and only 4 death certificates.

DISCUSSION

Through our analyses, we found that *Salmonella* infection accounted for more deaths than did infection with any other bacterial pathogen under FoodNet surveillance during 1996–1999. The 1996 chart review data indicated that, among the persons who died with *Salmonella* infection, the organism contributed to the deaths of most of the patients. Our overall case-fatality rate of 0.6% for culture-confirmed *Salmonella* infections is lower than a previous estimate [4, 5]. However, *Salmonella* infection was included as a cause of death on fewer than one-half of the death certificates or hospital charts, which suggests that the number of deaths caused by *Salmonella* is greatly underreported. Deaths caused by *Salmonella* occurred primarily among adults with serious underlying disease.

Salmonella continues to be a common pathogen that can cause severe and costly illness. Our data demonstrate that, although only 11% of infections occurred among persons aged ⩾60 years, 23% of *Salmonella*-related hospitalizations and 59% of *Salmonella*-related deaths occurred in this age group. These rates are of particular concern, because only 16% of the FoodNet population was aged ⩾60 years during this time, and the proportion of the population in this age group is projected to increase in upcoming years. Earlier work has suggested that persons with weakened immune systems and those who have recently received antimicrobial agents are at higher risk for *Salmonella* infection [10]. Our chart-review data suggest that these same groups are also at increased risk for death. Immunocompromising conditions or chronic illnesses that can be immunocompromising were documented in all of those who died with *Salmonella* infection, and 6 of 15 had received an antimicrobial agent before the onset of illness.

Table 3. Clinical findings from chart reviews of 15 patients who died with *Salmonella* infection.

Patient	Age, in years, sex	Race	*Salmonella* serotype	Site of isolation	Symptoms before hospitalization		Days in hospital	Major illnesses/conditions
					Fever	Diarrhea		
1	57, M	White	Dublin	Blood	Yes	No	Unknown	Chronic obstructive pulmonary disease
2	71, M	White	Group B[a]	Blood	Yes	No	16	Leukemia, systemic lupus erythematosus
3	46, M	Black	Lomalinda	Peritoneal fluid	No	No	78	Cirrhosis
4	43, F	White	Enteritidis	Blood, stool	Unknown	No	9	Gastrointestinal ulcer disease, hepatitis C, cirrhosis
5	44, F	Black	Typhimurium	Blood	No	No	1	Neutropenia, malnutrition
6	66, M	Black	Group B[a]	Blood, urine	No	Yes	20	Malnutrition, alcoholism, liver disease
7	39, M	Black	Typhimurium	Blood	Yes	No	7	HIV
8	41, M	Black	Typhimurium	Blood	Yes	Yes	122	HIV
9	71, M	Black	Typhimurium	Blood, stool	No	Yes	6	Insulin-dependent diabetes, tuberculosis, corticosteroid therapy
10	45, F	Black	Typhimurium	Blood	Yes	Yes	3	HIV
11	87, F	White	Typhimurium	Blood, stool	Yes	Yes	1	Non–insulin-dependent diabetes, renal disease
12	74, M	Unknown	Dublin	Blood	No	No	2	Lung cancer, corticosteroid therapy, chemotherapy
13	45, F	Hispanic	Typhimurium	Blood	No	No	6	Congestive heart failure
14	22, F	Asian	Heidelberg	Blood, urine, stool	Yes	No	1	Pregnancy
15	70, F	White	Unknown	Stool	Yes	Yes	Unknown	Laryngeal cancer, chemotherapy during the preceding 3 months, leukopenia

[a] These isolates were not serotyped. Among group B isolates from humans reported to the Centers for Disease Control and Prevention, ~65% were serotype Typhimurium.

A high proportion of persons who died with a *Salmonella* infection had an invasive infection. Although most *Salmonella* infections resolve without antimicrobial treatment, such therapy can be life-saving for persons with invasive *Salmonella* infections [7]. Thirteen of 15 decedents with chart-review data available were treated with antimicrobial agents while hospitalized. The *Salmonella* isolates from the patients who died were not available for susceptibility testing, so it is not known whether antimicrobial resistance influenced the outcome for these patients. Antimicrobial resistance among *Salmonella* isolates has been increasing, and this increased resistance can affect clinical outcome [7–10].

Of the estimated $0.5–$3.2 billion in annual costs attributed to *Salmonella* infection in the United States, fatal cases cost $0.5–$3.8 million each, and each hospitalization may cost at least $5460 [2]. Costs associated with *Salmonella* infections stem mainly from the price of medical care and lost productivity, particularly for those who die [2]. Most persons who died of *Salmonella* infection in 1996 were hospitalized for ~1 week, and many had complications. Although preventing infections would be the most efficient method of reducing costs and morbidity, efforts to reduce the number of hospitalizations or the length of hospitalization could significantly reduce the costs of *Salmonella* infection.

Most salmonellosis is transmitted through food, and much of the increase in the number of *Salmonella* infections during the 1970s and 1980s was associated with changes in slaughter and food-production practices [10]. In particular, *S.* Typhimurium is commonly found on cattle, swine, and chicken carcasses, as well as in ground beef and ground pork [11]. From 1987 through 1997, *S.* Typhimurium was the most common serotype reported to the CDC and accounted for 23% of all reported *Salmonella* isolates [6]. Similarly, in our review, *S.* Typhimurium was the most common *Salmonella* serotype isolated from patients with fatal *Salmonella* infections. However, the higher rates of hospitalization among patients infected with other serotypes, such as Choleraesuis and Dublin, demonstrated the increased virulence potential of certain serotypes [5, 6]. These differences merit further study with larger numbers of patients.

Efforts to reduce the rates of severe morbidity and death from bacterial foodborne diseases should continue to include *Salmonella* as a major focus. A focus on measures to prevent or reduce levels of the bacterial contamination of meat, poultry, and other food products before consumer handling, such as pathogen-reduction plans with control points on farms and feedlots, in transport, and in slaughter and processing operations, could reduce the number of cases of foodborne *Salmonella* infection. Specifically, the effective implementation of the FSIS Pathogen Reduction/Hazard Analysis Critical Control

Table 4. Causes of death for 15 patients with *Salmonella* infection, FoodNet, 1996.

Patient	Cause(s) listed on hospital chart			Cause(s) listed on death certificate			*Salmonella* determined to have contributed to death on the basis of hospital chart review
	1st	2nd	3rd	1st	2nd	3rd	
1	Anterioseptal myocardial infarction	…	…	Ischemic cardiomyopathy	Myocardial infarction	…	Yes
2	Acute myelogenous leukemia	…	…	Acute myelogenous leukemia	Systemic lupus erythematosus	…	Yes
3	Hepatic failure, *Salmonella* peritonitis	Liver transplantion with subhepatic hematoma	Fungal septicemia	Cirrhosis	…	…	No
4	Upper gastrointestinal bleed	Cirrhosis	*Salmonella* sepsis	Not available	Not available	Not available	Yes
5	Sepsis with hypothermia	Pneumonia	Seizures	Sepsis with hypothermia	Pneumonia	Seizures	Yes
6	Renal failure	Rhabdomyolysis	*Salmonella* bacteremia	Renal failure	Rhabdomyolysis	*Salmonella* bacteremia	Yes
7	*Cryptococcus* meningitis	AIDS	…	*Cryptococcus* meningitis	AIDS	…	Yes
8	Hypoxemia from pneumonia	Hemoptysis	AIDS	Pneumonia	AIDS	…	Yes
9	Diabetic ketoacidosis	Altered mental status	Gram-negative bacterial bacteremia	Gram-negative bacterial bacteremia	Diabetic ketoacidosis	Myocardial infarction	Yes
10	Gram-negative bacterial sepsis	AIDS	Acute renal failure	Gram-negative bacterial sepsis	AIDS	Acute renal failure	Yes
11	Septicemia	Acute renal failure	…	Septicemia	Acute renal failure	…	Yes
12	…	…	…	Lung cancer	…	…	Yes
13	Respiratory arrest	…	…	*Salmonella* Typhimurium septicemia	Right heart failure	…	Yes
14	Acute respiratory distress syndrome	*Salmonella* sepsis	…	Respiratory failure	Sepsis	*Salmonella*	Yes
15	Dehydration	*Salmonella* enterocolitis	Laryngeal cancer	Dehydration	*Salmonella* enterocolitis	Laryngeal cancer	Yes

Point (HACCP) systems regulations in meat and poultry slaughter and processing plants likely contributed to decreases in the prevalence or levels of *Salmonella* in meat and poultry products [12]. Since its implementation in 1997, the Pathogen Reduction–HACCP systems regulations have led to a decrease in the prevalence of *Salmonella* in FSIS-regulated products [13]. Contaminated food can be made safe for consumption by pasteurization, irradiation, or proper cooking; such processes are especially important for higher-risk foods, such as ground beef, and for vulnerable populations, such as persons aged ⩾60 years, persons in nursing homes, and infants aged <1 year. At restaurants, the mandatory training and certification of food handlers could improve the safety of menu items. Retail food stores can increase the safety of items they sell by requiring suppliers to implement a food-safety plan that includes microbiological testing. At the consumer level, prevention efforts, such as intensified food-safety education for the public on proper handling and consumption practices, particularly among high-risk groups, could help reduce the number and severity of illnesses. Efforts at each of these levels are needed to reduce the burden of *Salmonella* infections and the resultant hospitalizations and deaths.

FOODNET WORKING GROUP MEMBERS

CDC: Frederick Angulo, Timothy Barrett, Michael Beach, Nancy Bean, Richard Bishop, Thomas Boyce, Laura Conn, Vance Dietz, Mary Evans, Cindy Friedman, Kate Glynn, Patricia Griffin, John Hatmaker, Peggy Hayes, Debra Helfrick, Thomas Hennessy, Mike Hoekstra, Lori Hutwagner, Beth Imhoff, Malinda Kennedy, Deborah Levy, Bill MacKenzie, Kathleen Maloney, Nina Marano, Paul Mead, Thomas Navin, Sarah Pichette, Robert Pinner, Sudha Reddy, Laurence Slutsker, Karen Stamey, Bala Swaminathan, David Swerdlow, Robert Tauxe, Thomas Van Gilder, Drew Voetsch, David Wallace, Stephanie Wong, and Samantha Yang Rowe. California: Sharon Abbott, Felicia Chi, Pam Daily, Marianne David, Mary Ann Davis, Lisa Gelling, Alexander McNees, Janet Mohle-Boetani, Nandeeni Mukerjee, Joelle Nadle, Jan O'Connell, Judy Rees, Kevin Reilly, Art Reingold, Gretchen Rothrock, Michael Samuel, Sue Shallow, Ben Silk, Duc Vugia, and Ben Werner. Connecticut: Gary Budnick, Matthew Cartter, Terry Rabatsky-Ehr, James Hadler, Robert Howard, Gazala Kazi, Aristea Kinney, Ruthanne Marcus, Donald Mayo, Patricia Mshar, Randall Nelson, Quyen Phan, Robin Ryder, Charles Welles. Georgia: Sabrina Burden, Molly Bardsley, Wendy Baughman, Paul Blake, Shama Desai, Monica Farley, Katherine Gibbs-McCombs, Laura Gilbert, Jane Koehler, Mina Pattani, Susan Ray, Matthew Sattah, Suzanne Segler, Kathleen Toomey, and Sabrina Whitfield. Maryland: Bernadette Albanese, Lillian Billman, Alicia Bustamante, Amy Carnahan, Michael Carter, Marcia Criscio, Yvonne Deane-Hibbert, Diane Dwyer, Lora Gay, Althea Glenn, Charmaine Gregg, Lee Harrison, Kelly Henning, Yvonne Hibbert, Kim Holmes, Jackie Hunter, Judith Johnson, Tobi Karchmer, Melissa Kent, J. Glenn Morris Jr., Lola Olabode, Peggy Pass, Jafar Razeq, Jeffery Roche, Dale Rohn, Christine St. Ours, Christian Steiner, Alexander Sulakvelidze, Frances Yarber, and Yongyu Wang. Minnesota: Jeff Bender, John Besser, Richard Danila, Valerie Deneen, Craig Hedberg, Julie Hogan, Heidi Kassenborg, Carlota Medus, Michael Osterholm, Kirk Smith, Dana Soderlund, and Julie Wicklund. New York: Bridget Anderson, Dianna Bopp, Hwa-Gan Chang, Kathy Carlton, Barbara Damaske, Nellie Dumas, Marie Fitzgerald, Karim Hechemy, Jonathan Hibbs, Julia Kiehlbauch, Dale Morse, Candace Noonan, Brian Sauders, Perry Smith, Nancy Spina, Cathy Stone, and Shelley Zansky. Oregon: Vijay Balan, Chris Biggs, Maureen Cassidy, Paul Cieslak, Emilio DeBess, David Fleming, Bill Keene, Stephen Ladd-Wilson, Lore Lee, Eileen Lorber, Steve Mauvais, Teresa McGivern, Beletshachew Shiferaw, Bob Sokolow, Regina Stanton, and John Townes. Tennessee: Brenda Barnes, Effie Boothe, Allen Craig, Diane Eigsti Gerber, Timothy Jones, William Moore, William Schaffner, and Pat Turri. US Department of Agriculture, Food Safety and Inspection Service: Arthur Baker, Ruth Etzel, Jill Hollingsworth, Peggy Nunnery, Phyllis Sparling, and Kaye Wachsmuth. US Food and Drug Administration, Center for Food Safety and Applied Nutrition: Sean Alterkruse, Ken Falci, Bing Garthright, Janice Oliver, and Clifford Purdy.

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